



*Regular Research Article*

# A Minimum Break Load Analysis of Smith Bracket Using Finite Element Method (FEM)

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**Abstract:** The study on the use of the Smith Bracket in towing operations highlights its critical role in securing towing connections, which require strong structural integrity, as mandated by IMO safety regulations. Using Finite Element Method (FEM) analysis, the stress distribution under various tensile loads was examined, and the simulation results indicated that the bracket design could safely withstand operational forces, making it suitable for towing applications. From the calculations, The Minimum Break Load (MBL) of the Smith Bracket was determined to be  $\pm 69$  tons by applying a Safety Factor (SF) of 4, and The Safe Working Load (SWL) was calculated to be 17.5 tons. These values indicate that the bracket meets the safety requirements and can withstand operational loads without failure. The combination of the IMO regulations, FEM simulations, and theoretical analysis ensures that the Smith Bracket is designed for safe and reliable towing operations.

**Keywords:** Smith Bracket Analysis; Towing Operation Safety; Finite Element Method

## 1. Introduction

Transportation plays a vital role in global economic growth, and maritime transport serves as the backbone of international trade. Over the years, advancements in transportation have driven significant innovations in ship design, leading to the development of more efficient, specialized, and environmentally friendly vessels[1][2]. The shipbuilding industry has continuously evolved to meet the demands of modern logistics, offshore operations and sustainability. This progress is closely linked to developments in engineering and material science, where the introduction of high-strength steel, composite materials, and computer-aided design (CAD) technologies has revolutionized ship construction and performance. These innovations not only enhance the structural integrity and safety of marine vessels but also contribute to reduced operational costs and increased functionality in various maritime sectors.

The Accommodation Work Barge (AWB) is a type of ship and a specialized marine vessel designed to provide living quarters and support facilities for personnel working on offshore projects, particularly in the oil and gas industry and marine construction. This ship serves as a floating accommodation when offshore platforms lack sufficient capacity and offer safe and habitable environments for extended stays at sea. Typically, they include living quarters, mess halls, recreational areas, and medical facilities, and may also feature helidecks and workshops.

Accommodation Work Barges (AWB) are designed as non-self-propelled vessels and require towing assistance for relocation. This towing operation is typically performed using powerful tugboats, such as anchor-handling tug supply (AHTS) vessels. The towing process must be carefully planned, considering the environmental conditions, vessel size, and strength of the towing equipment. A key

component of this operation is the Smith Bracket (or Smit-type towing bracket), which functions as a structural attachment point for the towline. According to the IMO regulations and classification rules, the design load for Smit-type brackets must be no less than 1.3 times the minimum breaking strength of the towline or the weakest component of the towing arrangement.

Refers to IMO rules: Classifications register rules and regulations; smit-type towing brackets and closed fairleads[3].

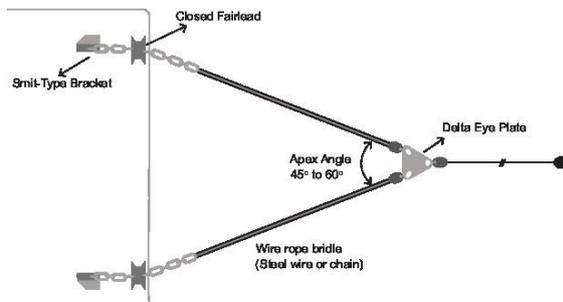


Figure 1. Smith bracket – Fairlead arrangement

The design load for Smit-type brackets and closed fairleads shall be no less than 1,3 times the minimum breaking strength of the provided towline or of the weakest component in the envisaged towing arrangement, if that is lower, applied at all possible angles of tow.

In shipbuilding engineering, all components have specific physical dimensions to withstand the loads applied to them, which must be measured accurately[4]. The Minimum Break Load/Breaking Strength (MBL) is a critical parameter used to define the structural capacity of the Smith Bracket under extreme loads. Determining this value ensures that the bracket meets the safety requirements for offshore towing operations. However, to ensure reliability and performance, a structural analysis using numerical methods, such as the Finite Element Method (FEM), is essential to simulate the stress distribution under various loading conditions. Therefore, the objective of this study is to analyze the MBL, Safe Working Load (SWL), and Safety Factor (SF) of the Smith Bracket under different tensile loading scenarios using FEM simulation, providing a comprehensive assessment of its suitability for safe towing operations.[5][6]

## 2. Materials and Methods

The object to be analyzed is the Smith bracket on the deck of the AWB. Logindo Reliance. This research uses the Finite Element Method (FEM), with modelling and structural simulation using Autodesk Inventor Student. The material structural model from Smith-Bracket is well-suited to research results in the vessel, including ship size data, Smith-Bracket size, material type, and operating tensile force.

To enhance methodological rigor, our FEM simulation setup comprising element types, mesh refinement, and boundary condition definitions was structured following validated practices in towing dynamics modeling, as demonstrated by Rodríguez-Luis et al. [7], who established correlation between FEM predictions and experimental data in marine towline simulations

The Smith Bracket model was meshed using 3D tetrahedral solid elements in Autodesk Inventor, with a mesh size refined in high-stress regions to ensure convergence. The boundary conditions included fixed supports at the base of the bracket and a uniaxial tensile load applied at the head of the bracket, representing the operational towline force. To enhance the credibility of our numerical model, validation was performed by comparing the calculated maximum stress values with the known yield strength of the bracket material, serving as a fundamental check within the elastic regime. This approach aligns with validated FEM practices reported in recent structural steel studies. [8] demonstrated a high correlation between FEM simulations and experimental results for steel clamp joints under tensile loads, confirming simulation accuracy through a quantitative comparison between the predicted stress and measured behavior.

Although direct physical testing of the Smith Bracket was not available, the methodology used, particularly defining realistic boundary conditions and mesh refinement, mirrors industry-standard validation techniques commonly adopted in marine structural simulations. Clearly documenting the mesh type, element selection, and boundary assumptions promotes reproducibility and

transparency in future studies and supports the reliability of the FEM model in predicting bracket performance under operational towing conditions.

### 2.1 Ship Data

The principal dimensions of the ships are presented in Table 1.

Table 1. Principle dimension of ship

Dimension	Notation	Value	
Length Over All	Loa	85,34	m
Breadth	Bmld	24,15	m
Depth	Dmld	7,87	m
Complement		150	Person

### 2.2 Materials

- Type of material : Carbon steel
- Young Modulus : 200 Gpa
- Density : 7,85 g/cm<sup>2</sup>
- Yield strength : 350 Mpa
- Poition rasio : 0,29
- Shear modulus : 77,51 Gpa

### 2.3 Safe working load, Breaking strength, & Safety Factor

The correlation between the MBL and Safe Working Load (SWL) is essential for ensuring operational safety. The SWL represents the maximum load that a Smith Bracket can safely handle during regular operations without compromising its structural integrity. Typically, SWL is derived from the MBL by applying a predetermined safety factor that accounts for uncertainties such as material imperfections, dynamic loading, and environmental conditions. The safety factor ensures that the bracket operates well below its breaking limit, preventing unexpected failures and extending its service life, which can be formulated as follows [9]:

$$F = m \times a \quad (1)$$

*Description:*

$F$  = Force load

$m$  = Mass object

$a$  = Acceleration (9,80665 m/s<sup>2</sup>)

$$SWL = \frac{MBL}{SF} \quad (2)$$

*Description:*

$SWL$  = Safety working load

$MBL$  = Minimum breaking load

$SF$  = Safety factor

The safety factor is a measure of security that indicates that a material or structure must have a strength greater than the maximum load it will experience by a certain factor to ensure safety and prevent failure. The safety factor can be calculated by comparing the allowable stress (yield strength) with the stress that occurs in the system.

$$SF = \frac{YSM}{AS} \quad (3)$$

*Description:*

$SF$  = Safety factor

$YSM$  = Yield strength material

$AS$  = Actual stress

The Safety Factor (SF) is the ratio of the MBL to the SWL, which acts as a buffer against unforeseen loading conditions. A higher safety factor indicates a more conservative design that provides greater reliability in extreme scenarios. For marine applications, the safety factor is typically mandated by classification societies and regulatory bodies to ensure compliance with the safety standards. A smith bracket can be designed by establishing the relationship between MBL, SWL, and SF, which guarantees both performance efficiency and operational safety, thereby reducing the risks associated with mechanical failures in maritime structures.

### 2.4 Desain and Modeling

Based on field survey data, below are the material specifications, sizes, and drawings of the smith brackets on Ship AWB. LOGINDO RELIANCE:



### 3. Results

#### 3.1 Load/force calculation

The towing force is based on In calculating the towing force on the Smith Bracket, Newton’s Second Law ( $F = ma$ ) underlies the finite element force equilibrium equations, similar to the cable dynamics models used in marine operations [7].

The force acting on the Smith bracket is a pulling force that occurs during the AWB ship-pulling activity of a tugboat. From the calculation results, the towing force acting on the Smith Bracket was obtained as follows:

Table 2. Calculation of load test (tensile)

No	Load/tensile (Ton)	Force (N)
1	25	245,166
2	50	490,332
3	75	735,498
4	85	833,565
5	90	882,598
6	100	980,665
7	125	1225,831

#### 3.2 Simulation running result

A Finite Element Method (FEM) simulation was conducted using Autodesk Inventor software, with the resulting loading model applied to the Smith Bracket, as illustrated in the following figures:

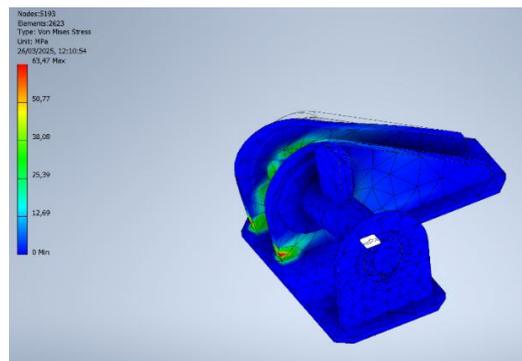
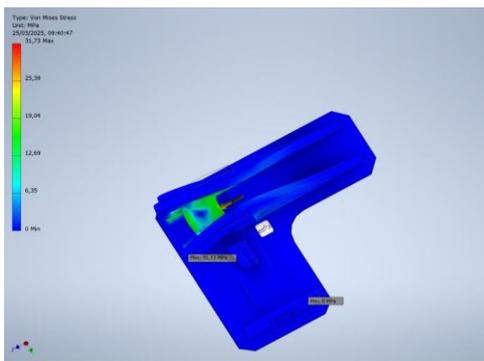


Figure 5. Von mises stress (Load 25 ton, 50 ton)

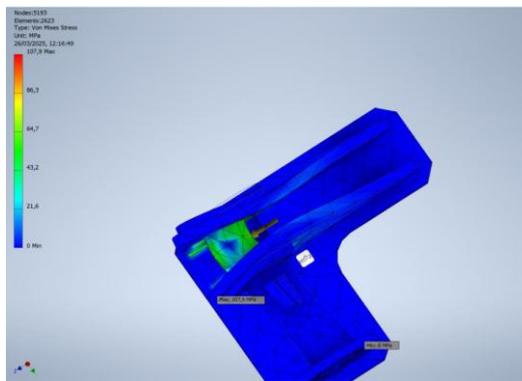
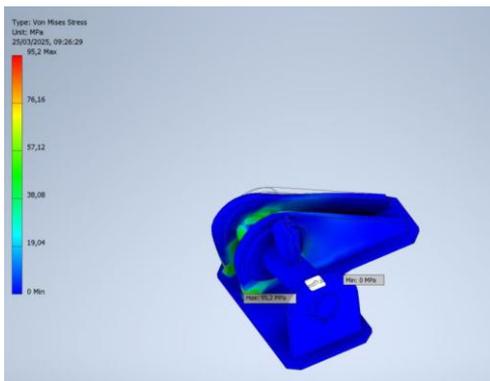


Figure 6. Von mises stress (Load 75 ton, 85 ton)

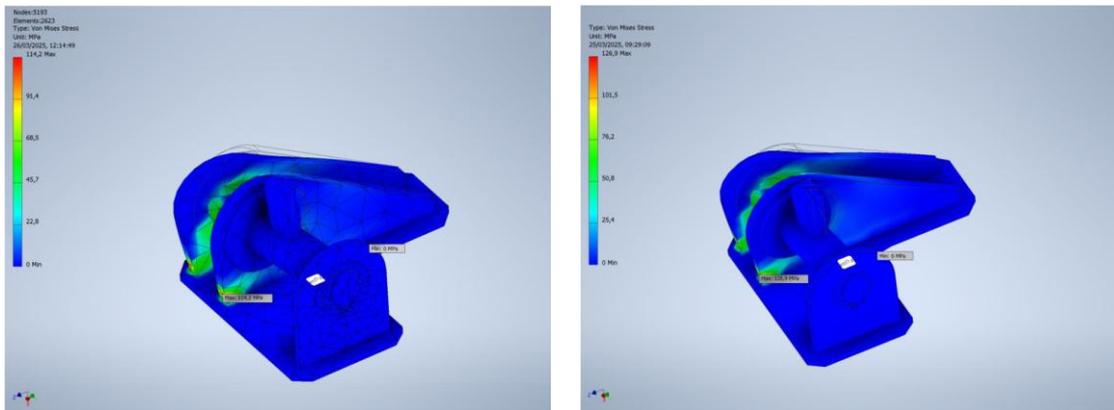


Figure 7. Von mises stress (Load 90 ton, 100 ton)

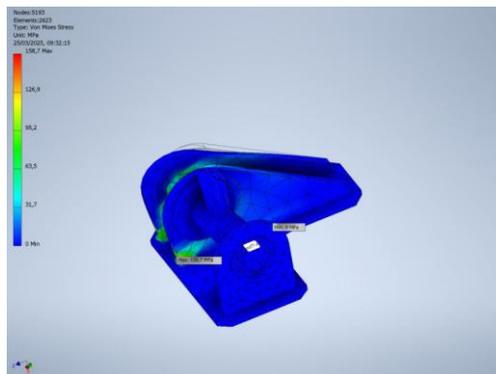


Figure 8. Von mises stress (Load 125 ton)

**4. Discussion**

The FEM simulation results based on the simulation test in Figure 1-7 for various test loads yielded the following stress values (von Mises stress):

$$SWL = \frac{MBL}{SF} \tag{2}$$

$$SF = \frac{YSM}{AS} \tag{3}$$

Table 3. Simulation result of load test, Von Mises Stress, and safety factor calculation

Load(Tensile) Test	Von Mises Stress	Safety factor
25	31,73	11,03
40	50,77	6,89
50	63,47	5,51
65	82,51	4,24
75	95,20	3,68
90	114,24	3,06
100	126,93	2,76
115	145,97	2,40
125	158,66	2,21

The relationship between the applied tensile load and the resulting von Mises stress demonstrated a consistent linear trend throughout the simulation data. As shown in Table 3 and Figures 5, 6, 7, and 8, each incremental increase in the applied load produced a proportional increase in the stress values. This behavior is characteristic of the elastic deformation within the yield range of the bracket material. This trend validates the use of linear static analysis under the assumed operational conditions, indicating that the Smith Bracket maintains a linear elastic performance throughout the evaluated loading range. This observation aligns with FEM-based studies on marine steel structures, such as that by Fitriadhy et al.[10], where load-stress linearity was a key indicator of model reliability and structural safety in the pre-yield regimes.

Empirical approaches, industry experience, and safety factors vary across industries. The higher the operational risk, the greater the Safety Factor required to ensure structural integrity and safety.

- Lift / Elevator Industry = 10 (SF)
- Crane / Lifting / Hoisting = 5 - 6 (SF)
- Towing = 3 - 4 (SF)

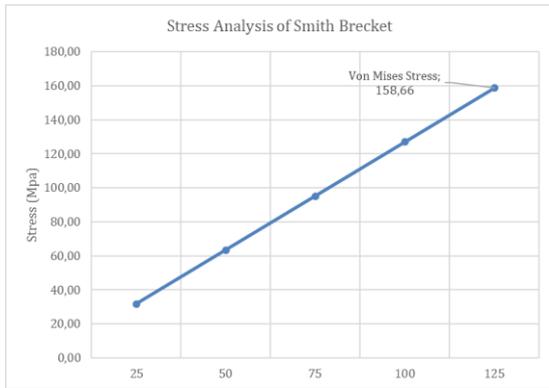


Figure 9. Graph of Stress analysis of Smith-bracket (Von Mises Stress)

- Minimum break load/breaking strength =  $\pm 69$  Ton
- Safe working load (SWL) = Breaking strength  $\div$  Safety factor (2)
- SWL =  $69 \div 4$  = 17,25 ton

The simulation results of the Smith Bracket under various tensile loading conditions revealed critical insights into its structural performance during towing operations. The stress distribution obtained using the Finite Element Method (FEM) indicated that the bracket could withstand operational loads within the allowable limits, with the maximum stress values remaining well below the yield strength of the material. This confirms the structural adequacy of the bracket design, aligning with the required safety factor of four, which is a common standard in towing and offshore operations[11].

To provide a practical context, based on the analysis results, the calculated Minimum Break Load (MBL) was 69 tons. By applying for a Safety Factor (SF) of 4, the Safe Working Load (SWL) was determined to be 17.25 tons. This ensures that the Smith Bracket operates within a safe load limit, thereby minimizing the risk of structural failure. The obtained values indicate that the bracket meets safety requirements, can be used reliably under the designated operational conditions, and complies with

international maritime rules, particularly the IMO and classification society standards (for example, ABS and DNV), which requires a towing component to sustain loads at least 1.3 times the expected maximum[3], This is also in line with operational challenges and safety modeling discussed by Kuncowati et al.[12], who emphasized the need for robust towing components in Indonesian shipping lanes. Furthermore, Kyaw [4] highlighted the increasing reliance on simulation-based design tools, such as FEM, to drive innovation and structural optimization in modern maritime technology systems. The values obtained validate that the Smith Bracket meets real-world operational standards. Similar research using FEM on marine towing and structural components, such as the simulation-based analysis of marine brackets by Serani et al., revealed consistent safety margins and stress behaviors under dynamic conditions [13].

In contrast, Ion ar. al [14] applied FEM in their study of general marine structural design, focusing on the static analysis of beam and plate elements using generalized coordinates. Although their study supports the use of FEM for marine structure analysis, it did not address localized high-stress components such as towing brackets. Additionally, Fitriadhy et al. [10] analyzed the nonlinear behaviors of catamaran hulls under hogging and sagging conditions using FEM. Their work focuses on global hull deformation rather than localized tensile stress in towing assemblies. This indicates a clear research gap addressed in the present study, which focuses on a critical connection point subject to high axial forces during towing operations.

By aligning numerical findings with practical offshore experience, regulatory safety margins, and comparative FEM studies, this study confirms that FEM is a valid and powerful tool for evaluating marine towing components. The results presented contribute to a better understanding of the localized structural integrity of towing systems and offer a replicable framework for similar bracket and hardware assessments in marine engineering. This is supported by Cavalheiro et al.[8], who demonstrated that integrating FEM simulations

with practical design verification can significantly enhance the accuracy of structural assessments in marine hardware applications, particularly for demountable steel joints under axial stress.

## 5. Conclusions

Based on the calculation results, the Minimum Break Load (MBL) of the Smith Bracket was determined to be  $\pm 69$  tons. By applying a Safety Factor (SF) of 4, the Safe Working Load (SWL) was calculated to be 17.25 tons. These values indicate that the bracket was designed to withstand loads well within its breaking limit, thereby ensuring operational safety and reliability under standard working conditions.

Finite Element Method (FEM) analysis further validated these calculations by simulating the structural response of the bracket under various tensile loads. The FEM results provided a detailed stress distribution map, highlighting the critical areas susceptible to high-stress concentrations. This approach enhances the accuracy of load capacity predictions and ensures that the bracket design satisfies safety standards. The correlation between the FEM analysis and theoretical calculations confirmed that the structure could withstand the expected operational forces without failing prematurely.

In conclusion, the combination of theoretical calculations and FEM simulations demonstrated that the Smith Bracket satisfied the required safety and performance criteria. The applied safety factor ensured a sufficient margin against unexpected loading conditions, thereby enhancing the overall reliability of the components. These findings support the suitability of the bracket for its intended application and provide confidence in its structural integrity and operational durability.

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**Competing interests:** This manuscript was

prepared independently, and the authors confirm that there are no competing interests associated with this work.

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